

DESIGN APPRECIATION OF A COMMERCIAL WASHING MACHINE

I. F. Odesola and Ikuenogbon Tedo

Mechanical Engineering Department, University of Ibadan, Ibadan, Nigeria.

Abstract : This paper focuses on the design appreciation of a washing machine or a washer. A washer is designed to clean laundry, such as clothing, towels and sheets. All washing machines work by using mechanical energy, thermal energy, and chemical action. Mechanical energy is imparted to the clothes load by the rotation of the agitator in top loaders, or by the tumbling action of the drum in front loaders.

Detailed components designs were carried out on all the major elements of the washing machine vis-a-vis: belt design, shaft design and bearing selection. From the analysis carried out, the following have been recommended: two v-belts, 39 mm diameter shaft, basic dynamic capacity for the bearing C is 15206.5 N. This work has established the fact that washing machine of various capabilities can be manufactured locally without compromising standards.

Introduction

A washing machine, or washer, is a machine assigned to clean laundry, such as clothing, towels and sheets. The term is mostly applied only to machines that use water as the primary cleaning solution as opposed to dry cleaning which uses alternative cleaning fluids.

All washer machines work by using mechanical energy, thermal energy, and chemical action. Mechanical energy is imparted to the clothes load by the rotation of the agitator in top loaders, or by the tumbling action of the drum in front loaders. Thermal energy is supplied by the temperature of the wash bath. (<http://www.consumerssearch.com>)

For many years clothing had been hand-washed by flushing water through the fabric to remove loose dirt, rubbing with soap to remove oils and stains. For clothes that were very dirty and caked with mud or dirt, there was need to constantly rub and flex the cloth to break apart solids and help the soap penetrate through thick, dry or sticky layers of soil on the cloth. (<http://www.sanyo.co.jp>)

The development of washing machine came up to reduce the problem of the scrubbing and rubbing processes, by providing an open basin or sealed container with paddles or fingers to agitate the clothing automatically.

The modern process of water removal by spinning did not come into use until electric motors were developed. Spinning requires a constant high-speed power source, and was originally done in a separate device known as an extractor. A load of washed clothing would be transferred from the wash tub to the extractor basket, and the water spun out. These extractors had some problems during usage and the major one was the unevenly distributed loads caused the machine to shake violently. Efforts were made to counteract the shaking of unstable loads, first by mounting the spinning basket on a free-floating shock-absorbing frame to absorb minor imbalance, and a bump switch to detect severe movement and stop the machine so that the load can be

Keywords : Design, Shaft, Energy, Machine, Appreciation

manually re-distributed. Nowadays, modern machines are now equipped with a sealed ring of liquid around the top of the basket that works to counteract any imbalance.

The first English patent under the category of Washing and Wringing Machines was issued in 1691. In Germany, Jacob Christian Schaffer's washing machine design was published in 1767. In 1782 Henry Sidgler was issued a British patent for a rotating drum washer.

In the United States, the first patent was given/granted to Nathaniel Briggs of New Hampshire in 1797. It is to be noted that a device that combined a washing machine with a wringer mechanism did not appear until 1843 when John Tumbull of Saint John, New Brunswick patented a 'Clothes Washer With Wringer Rolls'

As early as 1904 electric machines were advertised and discussed in newspapers. Around the late 1800s to early 1900s, Louis Goldenberg of New Jersey invented the electric washing machine.

In the UK and in most of Europe, electric washing machines did not become popular until the 1950s. The early electric washers were single tub, wringer-type machines, automatic washing machines being extremely expensive. Automatic washing machines did not become dominant in the UK until well into 1970s and by then were almost exclusively of the front-loader design. In the late 1990s, the British inventor James Dyson launched a type of washing with two cylinders rotating in opposite directions; which, it is claimed, reduces the wash time and produces cleaner results. In 1994, Stabber Industries released the system 2000 washing machine, which is the only top loading, horizontal-axis washer to be manufactured in the United States. The hexagonal tub spins like a front loading machine, only using about third of the water as conventional top-loaders. This factor has led to an Energy Star rating for its high efficiency^

In 2001, the first vertical axis high efficiency washing machine was introduced by Whirlpool Corporation. A wash -plate in the bottom of the tub nutated to bounce, shake, and toss the laundry around. As this happened, water containing detergent was sprayed on to the laundry.

In 2006, Sanyo introduced the first drum type washing machine with 'Air Wash' function. The washing machine uses only 50L of water in the recycle mode. In 2008, the University of Leeds created a washing machine that uses only a cup (about 280 ml) of water to carry out full wash. The machine leaves clothes virtually dry, and uses less than two percent of the water and energy otherwise used by a conventional machine. As such, this machine is capable of saving billions of litres of water yearly.(<http://www.whitegood.help.co.uk>)

In this paper, the focus will be to make the following available: Set of design calculations and sizing of the various elements of the washing machine, a detailed drawing of major components of the machine, an assembly drawing, and material selection for the components that constitute the washing machine.

2. Materials and Methods

A general arrangement of the machine is shown in flgs-4 and 5. Two valves are located on top of the machine, the first one admits hot water and the other one cold water. On one side of the drum, there is provision for a steam valve for heating water inside the cabinet. A thermometer mounted on the top of the machine gives the temperature of the water while the water level is observed using the sight glass located on top of the machine. The machine is loaded through a door at the front. At the rear of the machine a provision is made for the introduction of alkali and liquid soap solutions automatically. For detergents, either liquid or as dry powder are being added manually via a soapbox located at the front of the machine. At the rear of the machine is the cage drive mechanism and the electrical reversing control unit.

2.1 Cage and drive

This cage consists of a perforated drum bolted to steel trunnion, which is supported by a double ball bearing assembly bolted to the back plate of the outer casing. The general motor drives the cage through the medium of multiple vee belts that transmit the motor power from the drive pulley to the trunnion pulley. The drive is totally enhanced by a moulded glass fibre casing. The motor and trunnion bearings are grease lubricated.

2.2 Front cover, back cover and the drum

The front cover is rectangular in shape and this is where the door and the control buttons are attached. The back cover is similar to the front one except that a portion is cut off from it (triangular in shape) and also a circular cut for the rotating shaft covered with seal to prevent water leakage. The drum is along sheet rolled to form a cylinder. They are all made of galvanized steels.

2.3 Shafts and pulley

The shafts and pulley are manufactured via casting technology. Cast irons are selected grades of pig iron, which are remolded and cast in sand moulds. The carbon content of cast irons is generally between 2 and 4 percent. Although normal grades of cast irons are not all that strong but very brittle, they are widely used as engineering materials because of the following characteristics: very cheap, ease of melting and casting, good machineability and high damping capacity.

2.4 Basket, detergent dispenser, door hinges, door and door handle

These parts are all made of aluminum. Aluminum is one of the most abundant elements in the earth's crust, owing to its high affinity for oxygen. It cannot be reduced to metallic state by reduction with carbon or carbon monoxide, as in the case with many metallic oxides. Aluminum (99.99%) can be obtained by refining molten aluminum from the reduction cell in another electrolytic cell, the Hoopes process, with a molten electrolyte. Aluminum has good corrosion

2.5 The pipes

The inlet (hot and cold), steam exit and discharge pipes are produced by extrusion. The principles of backward and forward types of cold extrusion, often called impact extrusion, using open and closed dies are involved here. It was first used only with low strength ductile metals, such as lead, tin, and aluminum, for producing such items as collapsible tubes for toothpaste, shaving cream, and so forth. Cold extrusion is now widely used for forming mild steel parts.

2.5 Glasses

Glass is an amorphous, brittle material obtained by melting together a mixture of various compounds and supercooling the liquid to a temperature where viscosity exceeds 10^4 poise. Soda-lime-silica glass is the most common type of glass with an approximate composition of 15% Na_2O (Soda), 10% CaO (lime) and 75% SiO_2 (silica). Potash, K_2O may be used as partial replacement for lime. This type of glass is used in containers. It has good chemical, heat and electrical stability, with high temperature range.

3.0 Components design

3.1 Belt design

V-belts are employed generally to transmit power from the electric motor to the pulley which drives the shaft of the washer. This is used since it is not necessary to maintain an exact speed ratio between the two shafts. Power losses due to slip and creep amount to 3 to 5 percent for most belt drives. In this design, the shafts are parallel. Belt design involves either the proper belt selection to transmit a required power or the determination of the power that may be transmitted by a given v-belt. In this case the width of the belt is known and the thickness is assumed. The power transmitted by a belt drive is a function of the belt tensions and belt speed.

$$\text{Power} = (T_1 - T_2)V, \text{ Watts} \quad (1.0)$$

Where, T_1 = belt tension (tight side), N

T_2 = belt tension (loose side), N, V = belt speed, m/s

Equation (2.0) is used to determine the value of T_2 for both flat and V-belts when the width and thickness of belt are known.

$$\frac{T_2 - mv^2}{T_1 - mv^2} = e^{f\alpha} / \sin \frac{1}{2}\Phi \quad (2.0)$$

Where m = the mass of 1 m length of belt, v = belt velocity m/s, b = belt width, m , t = belt thickness, m , f = coefficient of friction between belt and pulley, a = angle of wrap, rad; Φ = groove angle for V-belt. (Hall et al., 1980)

The load carrying capacity of a pair of pulleys is determined by the one which

has the smaller $e^{f\alpha} / \sin \frac{1}{2}\Phi$

Excessive flexing of a belt will result in a shortened life. A minimum ratio of the diameter of a pulley to the thickness is about 30 for reasonable life span.

3.2 Belt selection

This can be achieved via appropriate equations or by use of tables and catalogues supplied by the manufacturers. In this exercise, relevant equations were used to select appropriate belts.

Angles of wrap for open belt were determined using equation 3.0. (Hall et al., 1980) $R - r$

$$\sin B = \frac{R - r}{C} \quad (3.0)$$

From fig. 1.0

$$\alpha_1 = 180 - 2B = 180 - 2\sin^{-1} \frac{R - r}{C} \quad (3.1)$$

$$\alpha_2 = 180 + 2B = 180 + 2\sin^{-1} \frac{R - r}{C} \quad (3.2)$$

The groove angle $\phi = 40^\circ$

The coefficient of friction between the belt and the washer pulley = 0.2

The coefficient of friction between the belt and the motor pulley = 0.2

The cross section of the belt is $b_2 = 10$ mm wide at the top and $b_1 = 4$ mm wide at the bottom by $d = 9$ mm (depth)

Mass of each belt, $m = btp$ where b = belt width, t = belt thickness, p = belt density.

The maximum allowable stress in the belt = 2MPa.

The pitch diameter of the V-belt on the flat pulley is determined by assuming that the pitch diameter is measured to the centroid of the belt section.

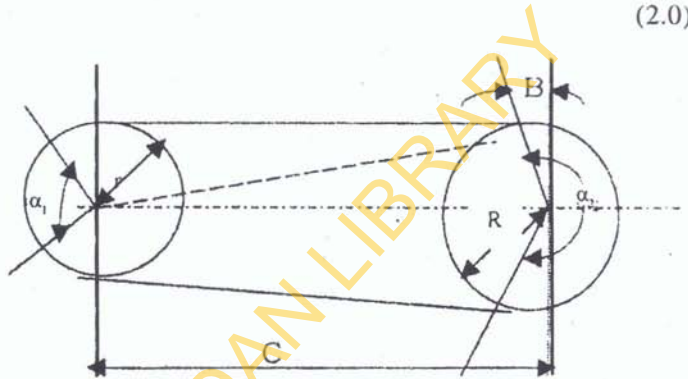


Fig. 1.0 : Belt selection (Angle of wrap calculation procedure)

Distance from base to C.G is

$$\bar{x} = \frac{d(b_2 + 2b_1)}{3(b_1 + b_2)} = \frac{9(4 + 20)}{3(4 + 10)} = 5.14 \text{ mm}$$

Pitch diameter of larger pulley = $500 + 2(5.14) = 510.28 \text{ mm}$, or pitch radius = 255.14 mm

For small pulley,

$$\alpha_1 = 180^\circ - 2\sin^{-1}[(255.14 - 65)/100] = 158.08^\circ$$

$$\alpha_2 = 180^\circ + 2\sin^{-1}[(255.14 - 65)/100] = 201.92^\circ$$

Comparing the capacities, $e^{f\alpha/\sin 1/2\Phi}$ of the two pulleys.

For small pulley, $e^{f\alpha/\sin 1/2\Phi} = 5.02$

For larger pulley, $e^{f\alpha/\sin 1/2\Phi} = 7.85$

Therefore, the larger pulley governs the design

The area of one belt = $1/2(b_1 + b_2)d = 1/2(0.004 + 0.01)0.009 = 63 \times 10^{-6} \text{ m}^2$

The tension on the slack side of the belt is found from equation 2.0

$T_1 = \text{area of one belt} \times S_s$, where S_s is the allowable stress of the belt

$$= (63 \times 10^{-6})(2.4 \times 10^6) = 151.2 \text{ N } T_2 = 71.81 \text{ N}$$

Power per belt, from equation 1.0 = 2494.44 W

Number of belt required = Power transmitted by motor/power per belt = $3000/2494.44 = 1.2$

Two(2) belts are recommended.

3.3 Shaft design

Shaft design focuses the determination of the correct shaft diameter to ensure satisfactory strength and rigidity when the shaft is transmitting power under various operating and loading conditions. Shafts are usually circular in cross-section, and may be either hollow or solid. Solid shaft was considered in this design. Shafts are usually subjected to torsion, bending and axial loads. It is assumed that the shaft materials obey Hooke's law, isotropic and homogenous. In this exercise the shaft is made from commercial steel because of its stiffness and availability.

Bending and torsional moments are the two important factors influencing shaft design. The first basic step is to draw bending moment diagram for the loaded shaft. From the bending moment diagram, the points of critical stress is determined. The torsional moment acting on the shaft is determined from equation (3.3)

$$M_e = \frac{kW \times 1000 \times 60}{2\pi \text{ rev/min}} = \frac{9550 \times kW}{\text{rev/min}} \text{ Nm} \quad (3.3)$$

The ASME cod equation for a solid shaft of this type, having little or no axial loading is given by equation(3.4).(Hall et al.,1980)

$$d^3 = \frac{16}{\pi S_s} \sqrt{(K_b M_b + K_t M_t)^2} \quad (3.4)$$

Where d = diameter of the shaft

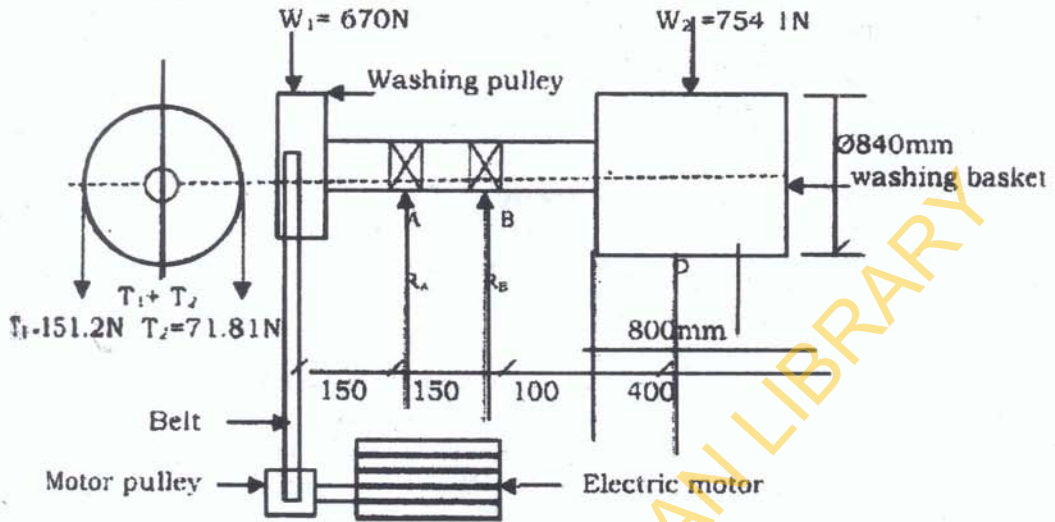
S_s = allowable stress of the shaft

M_t = Torsional moment

K_t, K_b = Shock and fatigue factor for torsional and bending moment. For rotating shaft of this nature, $K_t = 1.5, K_b = 2.0$

An appropriate method has been used to determine the masses of washing basket and washing clothes. The washing basket sheet is unfolded to form a flat sheet of length 2.62 m and 0.8 m wide.

Total number of holes(perforations) on this sheet = 806.



Thickness of each hole = $t_h = 0.004 \text{ m} = 4 \times 10^{-3} \text{ m}$
 Diameter of each hole = $R_h = 75 \times 10^{-4} \text{ m}$
 Therefore, volume of each hole = $\pi R_h^2 t_h = 3.142 \times (7.5 \times 10^{-4}) \times 0.004 = 71 \times 10^{-8} \text{ m}^3$
 Total volume of 806 holes = $57 \times 10^{-5} \text{ m}^3$
 Outer radius of the basket = $R_{ob} = 0.424 \text{ m}$
 Inner radius of the basket = $R_{ib} = 0.420 \text{ m}$
 Height of the basket = $h_b = 0.8 \text{ m}$
 Volume = $\pi h_b (R_{ob}^2 - R_{ib}^2) = 3.142 \times 0.8 [(0.424)^2 - (0.42)^2]$
 $= 85 \times 10^{-4} \text{ m}^3$

Volume of the perforated part = Volume of basket - Volume of holes = $85 \times 10^{-4} - 57 \times 10^{-5}$
 $= 79.3 \times 10^{-4} \text{ m}^3$

Volume of the back plate = $\pi R^2 t = 3.142 \times (0.42)^2 \times 0.004 = 222 \times 10^{-5} \text{ m}^3$

Total volume of the sheet washer basket = Volume of the back plate + volume of the perforated part. = $79.3 \times 10^{-4} + 22.2 \times 10^{-4} = 101.5 \times 10^{-4} \text{ m}^3$

Density of the sheet basket = density of pure aluminum = $\rho_s = 2.7 \times 10^3 \text{ kg/m}^3$

Mass of sheet basket = $2.7 \times 10^3 \times 101.5 \times 10^{-4} = 27.41 \text{ kg}$

Weight of the basket (mg) = $27.41 \times 10 = 274.1 \text{ N}$

The following procedure is adopted to estimate the maximum mass of clothes. For domestic washer of volume 0.046 m^3 , the maximum mass of cotton allowed is 5kg and therefore for a washing machine of volume 0.043 m^3 will hold a maximum of 48 kg of cotton.

This implies that the maximum weight of these clothes (cotton allowed per wash) is 480 N.

Total weight of the basket + maximum weight of clothes = $274.1 + 480 = 754.1 \text{ N}$

For the ungrooved rim, the volume is calculated below :

Diameter of the rim = $500 \text{ mm} = 0.5 \text{ m}$

Thickness of the rim (t) = $50 \text{ mm} = 0.05 \text{ m}$

Width of the rim (w) = $32 \text{ mm} = 0.032 \text{ m}$

Outer diameter of the rim = 0.5 m , radius = $R_{or} = 0.25 \text{ m}$

Inner diameter of the rim = 0.4 m , radius = $R_{ir} = 0.20 \text{ m}$

Volume of the ungrooved rim = $\Pi w(R_{of}^2 - R_r^2) = 3.142 \times 0.032(0.25^2 - 0.20^2) = 226 \times 10^{-5} \text{ m}^3$

Volume of the grooved out portion of the rim is now evaluated thus :

Outer diameter = 0.5 m, Outer radius = $R_o = 0.25 \text{ m}$.

Thickness = 0.0009 m = t, inner radius = $R_i = 0.24 \text{ m}$

Width = w = 0.01 m

The volume of the grooved out portion of the rim = $\Pi w(R_o^2 - R_i^2) = 3.142 \times 0.01 \times (0.25^2 - 0.24^2) = 15 \times 10^{-5} \text{ m}^3$

Total volume of the grooved portion = $15 \times 10^{-5} \times 2 = 30 \times 10^{-5} \text{ m}^3$

For the spokes :

Length of each spoke(L) = 12 mm = 0.012 m

Thickness(t) = 25 mm = 0.025 m

Width(w) = 50 mm = 0.05 m

Volume of each spoke = $L \times t \times w = 0.012 \times 0.025 \times 0.05 \text{ m}^3 = 15 \times 10^{-5} \text{ m}^3$

Total volume of five spokes = $5 \times 15 \times 10^{-5} \text{ m}^3 = 75 \times 10^{-5} \text{ m}^3$

For the hub :

Outer diameter of the hub = 160 mm = 0.16 m, Outer radius = $R_o = 0.08 \text{ m}$

Inner diameter of the hub = 50 mm = 0.05 m, Inner radius = $R_i = 0.025 \text{ m}$

Thickness of the hub, (t) = 32 mm = 0.032 m

Volume of the hub = $\Pi t(R_o^2 - R_i^2) = 3.142 \times 0.032(0.08^2 - 0.025^2) = 578 \times 10^{-5} \text{ m}^3$

Total volume of the rim :

Volume of the ungrooved - Volume of the grooved portion = $226 \times 10^{-5} - 30 \times 10^{-5} = 196 \times 10^{-5} \text{ m}^3$

Total volume of the pulley = volume of the rim + volume of the spoke

= $196 \times 10^{-5} + 75 \times 10^{-5} + 578 \times 10^{-5} = 849 \times 10^{-5} \text{ m}^3 = 8.49 \times 10^{-3} \text{ m}^3$

Mass of pulley = density of pulley \times volume of pulley = $7.87 \times 10^3 \times 8.49 \times 10^{-3} = 67 \text{ kg}$

The weight of the pulley = $67 \times 10 \text{ N} = 670 \text{ N}$

Total downward force on the washer pulley $670 + 223 = 893 \text{ N}$

Total downward force on the washing basket = weight of basket + maximum weight of clothes = 754.1 N

From fig.2.0 :

$R_A + R_B = 893 + 754.1 = 1647 \text{ N}$

Taking moment about B,

$R_A \times 0.15 = 754.1 \times 0.3 - 893 \times 0.3$

$R_A = 177.8 \text{ N}$ and $R_B = 1369.2 \text{ N}$

Bending Moment, M_b :

(i) $0 < x < 150$, $M_b = -893x$

(ii) $150 < x < 300$, $M_b = 893x + 277.8(x - 150)$

(iii) $300 < x < 800$, $M_b = -893x + 277.8(x - 150) + 1369.2(x - 300)$

From (i), when $x = 0$, $M_b = 0$

$x = 150$, $M_b = -133.95 \text{ N at A}$

(ii) when $x = 150$, $M_b = -133.95 \text{ N at A}$ $x = 300$, $M_b = -220.23 \text{ N at B}$

(iii) When $x = 300$, $M_b = -226.23 \text{ N at B}$

From the bending moment diagram, the points of critical bending stress are determined.

$M_b (\text{MAX}) = 226.23 \text{ N}$,

$M_i (\text{MAX}) = 23.88 \text{ N}$

S_s (allowable) = 40 MN/m² for shaft with keyway. (Hall et al., 1980)

From equation (3.4) :

$d = 0.0386m = 38.6$ mm, 39 mm diameter is recommended.

3.4 Bearing selection

Deep groove ball bearings are selected for this exercise. They are rigid, non-separable radial bearings. Their balls are guided in deep grooves in the inner and outer rings. Resultant load on the bearing is :

$$R = \sqrt{(277.8)^2 + (1369.2)^2} = \sqrt{1951881.4} = 1397.1N$$

The specific dynamic capacity C required for each bearing is 15,206. From the SKF bearing catalogue, the minimum sizes of single row deep groove bearing with the determined C is selected.

Table-1.0 : Bearing selection

Bearing	Basic dynamic capacity C(N)	Minimum shaft shoulder diameter(mm)	Inner Race maximum diameter(mm)	Bore(mm)	Outside diameter(mm)
6403	17,600	23.5	32.4	17	62
6305	17,300	31.5	36	25	62
6206	15,000	35.0	40.3	30	62
6207	14,600	41.5	46.9	35	72

Table-2.0 : Final selection

Bearing	Basic dynamic capacity C(N)	Minimum shaft shoulder diameter(mm)	Inner Race maximum diameter(mm)	Bore(mm)	Outside diameter(mm)
6206.5	15,206.5	39	44.36	33	68

Since the diameter D of the shaft, based on deflections is 39 mm, the minimum shoulder diameter has been selected using interpolation from table-1 and the result is shown in table-2.0

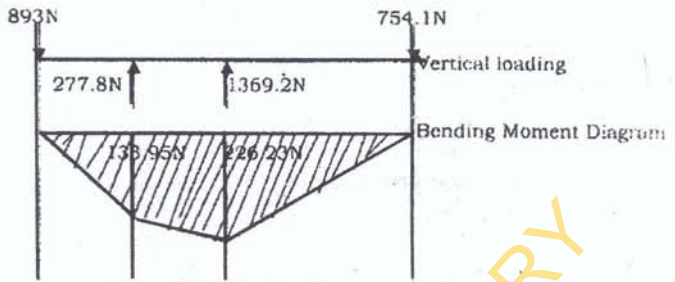


Fig-3.0 : Bending moment diagram

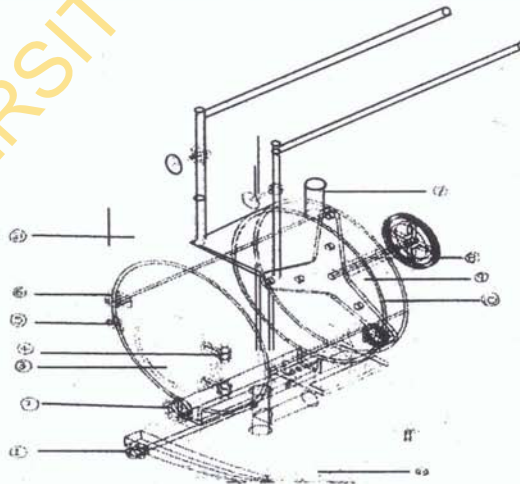


Fig-4 : Assembled drawing of the washing machine (from view)

Table-3.0 : Machine components (1)

Items	Description	Materials	No.
1	Drain valve lever	Mild steel	1
2	Site glass	Glass	1
3	Door	Stainless steel	1
4	Door hinge	Stainless steel	1
5	Door Lock	Cast iron	1
6	Detergent dispenser	Stainless steel	1
7	Steam vent	Mild steel	1
8	Bearing support	Galvanized steel	1
9	Washing basket	Aluminium alloy	1
10	Outer drum(tub)	Galvanized steel	1
11	Machine support	Mild steel	1
21	Front plate	Galvanized steel	1

Table-4.0 : Machine components (2)

Items	Description	Materials	No.
12	Motor pulley	Cast iron	1
13	Electric motor(cage)	Cast iron	1
14	Washer shaft	Cast iron	1
15	Bearing casting	Mild steel	1
16	Back plate	Galvanized	1
17	Cold water pipe	Mild steel	1
18	Hot water pipe	Mild steel	1
19	Drain pipe	Mild steel	1
20	Hexagonal Nut	Mild steel	4

Results and Conclusion

Table-1 shows the bearing selection procedure for the machine considering all the loads during operation while Table-2 displays the final selection of the bearing.

Tables 4 and 5 show components parts of the washing machine for ease of local manufacturing.

Fig-1 shows among other things the procedure for the calculation of angle of wrap for belt selection.

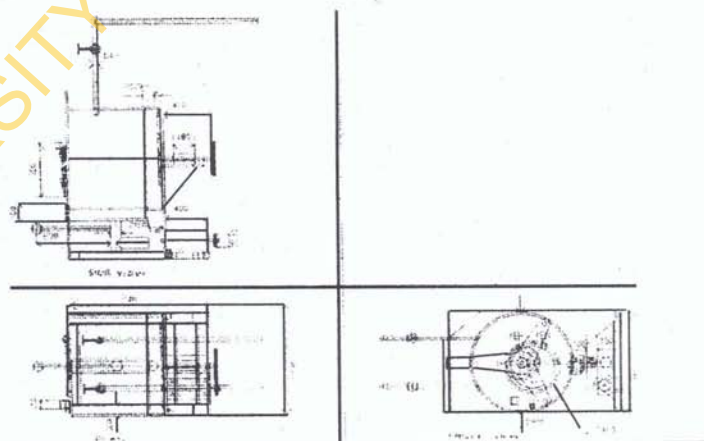


Fig-5 : Assembled drawing of the machine (orthographic)

Figs-2 and 3 show all the forces that are acting vertically on the main shaft of the washing machine bending moment diagram to determine the critical bending stress on the shaft respectively.

Detailed components designs were carried out on all the major elements of the washing machine vis-a-vis: belt design, shaft design and bearing selection. From the analysis carried out, the following have been recommended: two v-belts, 39 mm diameter shaft, basic dynamic capacity for the bearing C is 15206.5 N. This work has established the fact that washing machine of various capabilities can be manufactured locally without compromising standards.

From this exercise, it is evident that washing machines of different capacities can be manufactured locally in Nigeria without compromising standards. However, there is need for more research work in this direction and grants to be made available to create a centre where fabrication and experimental activities will be carried out continuously until the cost of production is within the acceptable limit.

Acknowledgement

The access given to us at Independence Hall, University of Ibadan to use the washing machine in their Laundry section is hereby acknowledged.

REFERENCES

- Anita, O.O and A. Offiong. (2005): "Optimum impact energy for palm nuts cracking", Global journal of Mechanical Engineering, 6(1):8-12.
- Bethune, J.D. (2006): Engineering Graphics with AutoCAD. 2006 Ed., Pearson International. U.S.A.
- Hall, A.S, Holowenko, A.R., Laughlin, G.M ,Hills,P.C and Bennett, M.D. (1982): Schaum Outline of Theory and Problems of Machine Design", SI(metric) edition, Mc Graw Hill Book Company, Singapore, Pp. 113-129.
- Massey, B.S. (1980): Mechanics of Fluids. 4th Ed. English Language Book Society and Van Nostrand Reinhold company. London.
- Odesola, I.F. and Salami, B.O. (2004): Development and Evaluation of Fluid Mechanics Laboratory Curriculum: A case study of the University of Ibadan, Nigeria" Global Journal of Mechanical Engineering, Vol. 5, pp. 32-37.
- Odesola, I.F., Olamide, O.O and W.A.Sanni(2002): "Performance Evaluation of a locally fabricated Crusher", Nigerian Journal of Engineering Research and Development, 1(4):54-58.
- Ogedegbe, T.I and Aderoba, A.A. (2002): A Computerized approach to Design of Mechanical Power Transmission Shafts" Nigerian Journal of Engineering Research and Development, 1(4): 36-46.
- Oladejo, S.A.(2000): Design and construction of a modified power supply system incorporated into an electronic circuit constructor", The Engineer, 1(1):20-30.
- Oluwole, O.O, Oloruntopa, D.T. and Awheme, O. (2008): Effect of zinc plating of low carbon steel on corrosion resistance in cocoa fluid environment". Materials and Design, Vol. 29:1266-1274.
- "Washing Machine Reviews ([http://www.consumersearch.com/www/house and home/washing machine-reviews](http://www.consumersearch.com/www/house%20and%20home/washing-machine-reviews))" (09-07-2008).
- "Electric Washing Machines the Latest. Housewives can do Washing in One-third the Time,"Des Moines Daily Capitol, November 2, 1904, p. 13
- "<http://www.whitegoodshelp.co.uk/wordpress/why-cant-modern-washing-machines-rinse-properly/>"
- Mothers and Daughters of Invention: Notes for a Revised History of Technology, Autumn Stanley, Rutgers University Press, 1995, p.301.
- http://www.sanyo.co.jp/koho/hypertext4-eng/0602/0202-1_e.html.